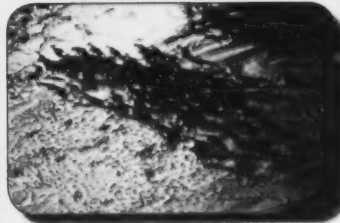


Forest-Dwelling Woodland Caribou in Ontario

CNFER Research Workshop Report

Barrie, Ontario

October 31 - November 2,
2006



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May 2007

(Centre for Northern Forest Ecosystem Research Information Paper 001)
Forest-Dwelling Woodland Caribou in Ontario: CNFER Research Workshop Report

Available in print: ISBN 978-1-4249-4665-5
Available also on the Internet (PDF): ISBN 978-1-4249-4666-2

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Single copies of this publication are available from:

Centre for Northern Forest Ecosystem Research
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Please cite as:

Rodgers, A. R., B. A. Allison, K. D. Wade, and E. P. Iwachewski. 2007. *Forest-Dwelling Woodland Caribou in Ontario: Research Workshop Report*. Information Paper CNFER IP-001. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada. 27pp.

EXECUTIVE SUMMARY

The Centre for Northern Forest Ecosystem Research (CNFER), an applied research section of the Ontario Ministry of Natural Resources (OMNR), conducted a Forest-dwelling Woodland Caribou Research Workshop in Barrie, Ontario, from October 31 – November 2, 2006.

The need for new research and management of woodland caribou (*Rangifer tarandus caribou*) in Ontario has been well documented through published research articles, workshops, advisory committees, summary reports, and independent forest audits. Prior to this workshop, a comprehensive summary of caribou questions and information needs was compiled from a variety of source documents, including a draft of the *Recovery Strategy for Forest-Dwelling Woodland Caribou (Rangifer tarandus caribou) in Ontario* (February 2005). To identify the most important caribou research issues, CNFER staff surveyed individuals and organizations known to have had involvement or interest in woodland caribou through work on Forest Management Plans, Protected Areas, Species at Risk, policy development, wildlife management, conservation issues, or research. These included OMNR managers and staff as well as resource industry, non-governmental groups, academic, tourism, federal, and municipal government representatives.

The key uncertainties identified in the CNFER survey were all related to the direct and indirect effects of disturbance (e.g., by commercial forestry operations) on the occurrence of forest-dwelling woodland caribou in Ontario. Habitat selection at multiple scales and predation were clearly identified as important factors in the most highly ranked caribou research issue, and road and other corridor effects were among the most important subject areas identified for further research. The objective of the CNFER Forest-Dwelling Woodland Caribou Research Workshop was to review and refine these issues into rigorous scientific hypotheses in support of preliminary designs for an adaptive management approach to the conservation of caribou in Ontario.

The workshop began with a series of presentations, including several from neighbouring jurisdictions (i.e., Alberta, Manitoba, and Québec), to provide context for the design of future caribou research in Ontario. Principles of Decision Analysis and Adaptive Management (DAAM) were subsequently used to guide further program development. Workshop participants were assigned to 4 autonomous working groups that each identified dependent and independent variables, the quality and availability of necessary data, and generated "word models" based on competing hypotheses regarding the key uncertainties affecting caribou populations. Twenty-two dependent and 44 independent variables were identified. The most often listed and important dependent variable was probability of occurrence, and all groups selected at least one independent variable related to each of roads, predation, and habitat pattern. Working groups assessed the spatial and temporal scales required to evaluate the models under each of 3 experimental options: model simulation, retrospective analysis, and field experiments. Spatial and temporal scales of experimental design varied from 3,000 km² to over 100,000 km² and from 5 to 50 years, respectively.

The general word models/hypotheses and initial designs for adaptive management developed during this workshop address the most important caribou research issues identified in the CNFER survey: the probability of forest-dwelling woodland caribou occurrence is likely a function of some combination of roads, predation, and habitat pattern best addressed at multiple spatial scales with an Active Adaptive Management approach that includes spatial controls for those factors.

To date, CNFER has completed the first 7 of 10 steps in a DAAM program and the initial stage of step 8 (design and implementation of management experiments according to sound principles of experimental design). The next steps will be to further refine the general word models/hypotheses into a subset of competing models, provide details of the experimental design (e.g., treatments, replicates), and identify potential study areas. To reach the implementation stage, CNFER will continue to pursue potential research partnerships with provincial and federal government and non-governmental organizations and individuals, including university academics, industry representatives, First Nations, and environmental groups.

SOMMAIRE

Le Centre de recherche sur l'écosystème des forêts du Nord (CNFER), section de recherche appliquée du ministère des Richesses naturelles (MRN) de l'Ontario, a dirigé un atelier de recherche sur le caribou des bois à Barrie, en Ontario, du 3 octobre au 2 novembre 2006.

En ce qui concerne le caribou des bois (*Rangifer tarandus caribou*) en Ontario, la nécessité d'effectuer de nouvelles recherches et de modifier l'aménagement a été clairement établie dans des articles de recherche publiés et des rapports sommaires, par l'entremise de comités consultatifs, et lors d'ateliers et de vérifications indépendantes en milieu forestier. Avant l'atelier du CNFER, un résumé complet des questions et des besoins d'information relatifs au caribou a été compilé à partir de sources diverses, y compris le document intitulé *Recovery Strategy for Forest-Dwelling Woodland Caribou (Rangifer tarandus caribou) in Ontario* (février 2005) [ébauche de la stratégie de rétablissement du caribou des bois (*Rangifer tarandus caribou*) en Ontario]. Afin de définir les plus importants thèmes de recherche sur le caribou, le personnel du CNFER a mené une enquête auprès de personnes et d'organismes reconnus pour l'intérêt qu'ils ont porté au caribou des bois lors de travaux en rapport avec les plans de gestion forestière, les zones protégées, les espèces en péril, l'élaboration des politiques, l'aménagement de la faune, les problèmes de conservation ou la recherche. Parmi eux, se trouvaient des gestionnaires et des membres du personnel du MRN de l'Ontario, ainsi que des représentants de l'industrie primaire, de groupes non gouvernementaux, du monde universitaire, du tourisme, du gouvernement fédéral et des administrations municipales.

Les principales incertitudes relevées dans l'enquête du CNFER étaient toutes liées aux effets directs et indirects de la perturbation (p. ex., les activités de foresterie commerciale) sur la présence du caribou des bois en Ontario. Le choix d'habitat à plusieurs échelles et la prédation se distinguaient clairement comme des facteurs importants dans le thème de recherche prépondérant concernant le caribou, et les effets liés aux routes et autres corridors figuraient parmi les plus importants domaines de recherche complémentaire. L'atelier de recherche du CNFER sur le caribou des bois avait pour objectif d'examiner et de préciser ces thèmes, afin d'en dégager des hypothèses scientifiques rigoureuses pour étayer des études préliminaires devant mener à une méthode de gestion adaptative dans la conservation du caribou en Ontario.

L'atelier a commencé par une série d'exposés, plusieurs d'entre eux donnés par des territoires de compétences voisins (c.-à-d. l'Alberta, le Manitoba et le Québec), afin de définir le contexte de la conception des futures recherches sur le caribou en Ontario. Par la suite, l'application des principes de l'analyse de décision et de la gestion adaptative a servi à orienter l'élaboration du programme. Les participants à l'atelier ont été répartis en groupes de travail autonomes, chacun chargé de déterminer des variables dépendantes et indépendantes, de vérifier la qualité et la disponibilité des données nécessaires, et de produire des « modèles de mots » fondés sur des hypothèses concurrentes relativement aux principales incertitudes touchant la population de caribous. Ainsi, 22 variables dépendantes et 44 variables indépendantes ont été reconnues. La probabilité de présence constituait la variable dépendante la plus souvent désignée et la plus importante, et tous les groupes ont choisi au moins une variable indépendante liée aux routes, à la prédation et aux types d'habitat. Les groupes de travail ont déterminé les échelles spatiales et temporelles requises pour évaluer les modèles en fonction de chacune des trois options expérimentales suivantes : la simulation sur maquette, l'analyse rétrospective et les expériences sur le terrain. Les échelles spatiales et temporelles du plan d'expérience allaient de 3000 km² à plus de 100 000 km², et de 5 à 50 ans respectivement.

Les hypothèses/modèles de mots généraux et les concepts initiaux de gestion adaptative qui ont été élaborés pendant l'atelier abordent les principaux thèmes de recherche sur le caribou qui sont relevés dans l'enquête du CNFER : la probabilité de présence du caribou des bois s'établit probablement en fonction d'une certaine combinaison de routes, de prédation et de types d'habitat, laquelle serait évaluée

de façon optimale au moyen de plusieurs échelles spatiales selon une méthode de gestion active adaptative comprenant des repères spatiaux pour ces facteurs.

À ce jour, le CNFER a terminé les sept premières des dix étapes du programme d'analyse de décision et de gestion adaptative, ainsi que le premier stade de l'étape 8 (conception et mise en œuvre d'expériences d'aménagement selon les principes judicieux du plan d'expérience). Les prochaines étapes consisteront à épurer les hypothèses/modèles de mots généraux en un sous-ensemble de modèles concurrents, à indiquer les détails du plan d'expérience (p. ex., traitements, répétitions) et à déterminer les domaines d'étude possibles. Pour atteindre le stade de la mise en œuvre, le CNFER continuera de former d'éventuels partenariats de recherche avec des organismes gouvernementaux provinciaux et fédéraux, des organismes non gouvernementaux et des particuliers, y compris des universitaires, des représentants de l'industrie, des membres des Premières nations et des groupes environnementalistes.

ACKNOWLEDGEMENTS

The Centre for Northern Forest Ecosystem Research would like to thank the workshop steering committee members, Dr. Jim Baker (Science Business Coordinator, OMNR Applied Research and Development Branch), Dr. Jim Schaefer (Associate Professor, Trent University), Dr. Ian Thompson (Research Scientist, Canadian Forest Service), and the workshop facilitator Dr. Tom Nudds (Professor, University of Guelph), for their excellent contributions in helping us plan and conduct the workshop, as well as their insightful comments in crafting this workshop report. Thanks to Tim Timmermann, Mike Buss, Gerry Racey, and JD Taylor for use of their photos, as well as Brooke Pilley (Information Officer, CNFER) for desktop publishing this report.

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INTRODUCTION

The need to address key uncertainties regarding the persistence of woodland caribou (*Rangifer tarandus caribou*) in Ontario has been well documented through published research articles, workshops, advisory committees, summary reports, and independent forest audits. Media reports and campaigns across Canada by a variety of environmental organizations have heightened public perception about the importance of woodland caribou as an indicator of the health of the boreal forest. The decline in woodland caribou range occupancy in Ontario has been recognized since the late 1940s and the boreal population of forest-dwelling woodland caribou is designated as "Threatened" both provincially (COSSARO 2005) and federally (COSEWIC 2002).

The Centre for Northern Forest Ecosystem Research (CNFER) located in Thunder Bay, is an applied research section of the Ontario Ministry of Natural Resources (OMNR). With many pressing issues related to forest-dwelling woodland caribou and a variety of potential directions to focus research, a comprehensive summary of caribou questions and information needs was compiled in November 2005 as part of the Northern Mammal Ecology Program at CNFER. Scientific and technical questions about woodland caribou ecology and management in Ontario were consolidated from a variety of source documents (Table 1) and grouped into 9 broad areas of

scientific enquiry; (1) Population management, dynamics and status, ecological dynamics; (2) Land use planning / policy and management; (3) Habitat: critical and core, forage, distribution and fire; (4) Forest management regimes (FMPs), disturbance and techniques; (5) Genetics/DNA and metapopulations; (6) Predator/prey dynamics; (7) Recruitment, survival, mortality, population limiting factors, cumulative impacts; (8) Road and other corridor effects; and (9) Inventory, monitoring and reporting. An initial list of 91 questions was refined to a final list of 42 by including only those questions that could be undertaken in a research program at CNFER, given its mandate and current expertise. Excluded questions involved research currently underway (e.g., genetic studies through the DNA Profiling and Forensic Centre at Trent University) or that may be undertaken by another unit within OMNR (e.g., determination of population size by the Inventory, Monitoring, and Assessment Section). Nonetheless, these additional research and monitoring studies may be closely linked with questions potentially addressed by a CNFER research program.

The final list of 42 questions, grouped by subject area, was used to develop a survey (Appendix A) that was distributed internally to OMNR staff who had involvement or interest in woodland caribou through work on Forest Management Plans, Protected Areas, Species at Risk, policy development or wildlife management, and externally to federal government colleagues, non-

Table 1. Sources of research questions used in the development of the CNFER - Forest-Dwelling Woodland Caribou Research Survey.

Author	Year	Document
Ontario Woodland Caribou Recovery Team (W. J. Rettie, editor)	Feb 2005	Recovery Strategy for Forest Dwelling Woodland Caribou in Ontario, Draft.
J. Chikoski, H. Gignac	Feb 2005	Caribou Technical Workshop summary, OMNR.
OMNR	2005	Strategy for Wolf Conservation in Ontario and Backgrounder on Wolf Conservation In Ontario.
T. J. Chowns	Aug 2003	State of the Knowledge of Woodland Caribou in Ontario, Report for Forestry Research Partnership.
Ontario Woodland Caribou Advisory Committee	Oct 2002	Minutes of the Meeting.
A. Harris	Jun 1999	Report on the Status of Woodland Caribou in Ontario, COSSARO Report.
K. M. Brown	Apr 1999	Planning the next Round of Caribou Habitat Research, Workshop Proceedings.

governmental individuals and university academics with interests in caribou. The survey was sent to a total of 262 individuals. Survey participants were asked to rate and rank the relative importance of the 9 subject areas, as well as the general and specific research questions within each, according to their perceived level of importance. They were then asked to select and rank the 3 most important research questions in the survey, regardless of subject area.

The survey results were summarized (Appendix A) and reported to all survey participants at the end of March 2006. The 3 most important subject areas identified for further research were: (1) Forest management regimes (FMPs), disturbance and techniques; (2) Land use planning / policy and management; and (3) Road and other corridor effects. There was also strong interest in additional research on (4) Population management, dynamics and status, ecological dynamics and (5) Recruitment, survival, mortality, population limiting factors, cumulative impacts. The most important caribou research issue, regardless of subject area, identified by both OMNR and external respondents was:

Evaluate effects of landscape disturbances created by commercial forestry operations on caribou populations (via individual caribou survival and mortality causes, recruitment, habitat selection at multiple scales, measuring changing abundance of moose, deer and predation by wolves and bears).

Secondary research issues identified as important in the survey were:

Determine the mechanisms driving forest woodland caribou population dynamics in modified landscapes, and

At what level of disturbance do caribou abandon previously occupied habitat (threshold of disturbance)?

To refine these research issues into rigorous scientific hypotheses and to formulate alternative experimental designs for their examination, a steering committee was established in June 2006 to develop the CNFER Forest-dwelling Woodland Caribou Research Workshop.

Members of the steering committee included Ed Iwachewski (Manager, CNFER), Art Rodgers (Research Scientist, CNFER), Brad Allison (Research Biologist, CNFER), Keith Wade (Project Biologist, CNFER), Jim Baker (Science Business Coordinator, OMNR Applied Research and Development Branch), Jim Schaefer (Associate Professor, Trent University), and Ian Thompson (Research Scientist, Canadian Forest Service). The steering committee outlined an initial agenda for the workshop and developed a list of potential facilitators and participants. Tom Nudds (Professor, University of Guelph) was invited to facilitate the research workshop and joined the steering committee in August 2006. The agenda was refined and invitations were sent to 38 potential government and non-governmental individuals, including university academics, industry representatives, and non-government environmental organizations. Including the steering committee, 32 participants (Appendix B) attended the CNFER Forest-dwelling Woodland Caribou Research Workshop held at the Kempenfelt Centre in Barrie, Ontario, October 31 – November 2, 2006.

WORKSHOP OVERVIEW

Over the 2-day period, the workshop progressed from the presentation of background information through research development to a discussion of next steps (Table 2). To begin, Ed Iwachewski welcomed participants and tasked them with the primary objective of the workshop: *to review and refine the most important caribou research issues identified in the CNFER survey into rigorous scientific hypotheses and to formulate preliminary experimental designs for their examination.* Keith Wade then reviewed the results of past workshops and the CNFER survey. To provide resource management context, 12 participants were invited to give presentations on the first afternoon and next morning of the workshop. Several presentations focused on the historical and current status of the species, scientific knowledge, and ecological pressures, including climate change, facing woodland caribou regionally in Ontario, as well as outside the province (i.e., Alberta, Manitoba, and Québec). Resource management practices related to forest-dwelling woodland caribou, as well as industry and environmental perspectives on

Table 2. CNFER Forest-dwelling Woodland Caribou Research Workshop Agenda.

Time	Topic	Title/Activity	Presenter(s)/Lead(s)
1:00	Introduction/Welcome	Day 1 Objectives	Ed Iwachewski/Tom Nudds
1:15	Moving Ahead	Past Workshops and New Survey Results (Top 3 Questions)	Keith Wade/Art Rodgers
1:30	State of Knowledge	History, Policy and Recovery Planning Process	Ted Armstrong
1:45	State of Knowledge	Future Demographic Trends	Jim Schaefer
2:00	Ontario Regional Status	Recent Studies in NE Ontario	Glen Brown
2:15	Ontario Regional Status	Recent Studies in NW Ontario	Ted Armstrong
2:30	Planning	Caribou Mosaics	Phil Elkie
2:45	Planning	Future Forest Policy	Bruce Ranta
3:00	BREAK		
3:30	Other Jurisdictions	Manitoba - Owl Lake Study Area	Vince Crichton
4:00	Other Jurisdictions	Québec - First Approaches in Forest Management	Réhaume Courtois
4:30	Other Jurisdictions	Alberta - Cumulative Impacts on Caribou	Elston Dzus
5:00	Summary	Day 1 Summary	Tom Nudds-facilitator
5:15	END DAY 1		
8:15	Day 2 Introduction	Day 2 Objectives	Tom Nudds-facilitator
8:30	Drivers	Climate Change Effects on Caribou Ecology	Ian Thompson/Jim Baker
8:45	Drivers	Caribou Research in Ontario: Perspectives from NCASI	Darren Sleep
9:00	Drivers	Social - ENGO Concerns/Drivers and Policy Concerns	Gillian McEachern
9:15	Analysis	Decision Analysis and Adaptive Management for Caribou in Ontario	Tom Nudds
9:45	Moving Ahead	Are There Other New Questions (or linked research questions)?	All/Tom Nudds-facilitator
10:15	BREAK		
10:30	Research Development	Develop Research Themes Using Top 3 Questions from CNFER Survey	Groups
11:00	Research Development	Further Refine Research Sub-themes	Groups
11:30	Research Development	Summarize and Discuss Sub-themes	All/Tom Nudds-facilitator
12:00	LUNCH		
1:00	Research Development	Dependent Variables	Groups
1:30	Research Development	Dependent Variables	Groups
2:00	Research Development	Dependent Variables	Groups
2:15	Research Development	Report from above session	Groups
2:30	BREAK		
3:00	Research Development	Independent Variables	Groups
4:00	Research Development	Independent Variables	Groups
4:30	Research Development	Report from above session	Groups
5:00	END DAY 2		
8:00	Day 3 Introduction		Tom Nudds-facilitator
8:30	Research Development	Report on Competing Word Models/Hypotheses	Groups
9:15	Research Development	Assign Degrees of Belief/Prior Probabilities to Models	Groups
9:45	Research Development	Assign Degrees of Belief/Prior Probabilities to Models	Groups
10:15	BREAK		
10:30	Research Development	Experimental Design	Groups
11:00	Hypotheses	Summary of Working Hypotheses and Experimental Designs	Tom Nudds-facilitator
11:30	Summary and Next Steps	Workshop Wrap-up	Tom Nudds/Ed Iwachewski

the overall management of the species in Ontario, were also subjects of individual presentations.

Workshop facilitator, Tom Nudds, presented a framework for *Decision Analysis and Adaptive Management* (DAAM). He emphasized that, traditionally, research and management have been considered "stand-alone" processes. Adaptive management, in contrast, is management undertaken to address key uncertainties about its effects – adaptive management is learning *while* doing. In this view, research and management are integrated (Lancia et al. 1996, Nudds 1998, MacDonald et al. 1999). Nudds outlined the necessary steps to complete an inclusive DAAM program for forest-dwelling woodland caribou in Ontario (Appendix C). He then reviewed the steps already completed and proposed that a continuation of the DAAM process could lead to the development of multiple hypotheses and preliminary experimental research designs to investigate the most important caribou research issues identified in the CNFER survey. Subsequently, workshop participants were assigned to four independent working groups (Appendix B), based on their area of expertise, non-government representation, and geographic origins, to pursue the next steps in the DAAM process.

Initially, each working group was asked to list and describe dependent and independent variables that may be associated with the most important caribou research issues identified in the CNFER survey. Working groups were asked to assess what data were needed to develop and calibrate models/hypotheses based on the dependent and independent variables, and which data sets were currently available, or could be obtained to predict caribou response to disturbance. Working groups then developed and ranked competing word models/hypotheses that in aggregate addressed all the uncertainties encompassed by the independent/predictor variables. At the conclusion of each stage, working groups summarized and reported the results of their discussions to all participants for further discussion and comparison with other groups.

Consideration was given to the temporal and spatial dimensions of potential experimental management options as well as the requirements

of mensurative versus manipulative experimental designs in the context of Active Adaptive Management. At the conclusion of the workshop, Tom Nudds summarized the results of the working group discussions and reviewed the 10 steps needed to complete an inclusive DAAM program for forest-dwelling woodland caribou in Ontario, noting those achieved during the workshop. Lastly, Nudds assessed whether participants had successfully addressed the 3 most important caribou research issues identified in the CNFER survey and thereby achieved the primary objective of the workshop.

BACKGROUND PRESENTATIONS

Short summaries of background presentations given on the first afternoon and next morning of the workshop, arranged by topic, are provided below. Copies of the original presentations, in PDF file format, are available from CNFER.

Moving Ahead

Keith Wade: Past Workshops and New Survey Results (Top 3 Questions)

Sources of research questions included in the CNFER – Forest-Dwelling Woodland Caribou Research Survey were summarized. The survey was sent to 262 people; OMNR staff, federal government employees, natural resource industries, academia, consumptive and non-consumptive non-governmental organizations (NGOs), tourism groups, and municipal government representatives. Survey organization into discrete "Subject Areas" and the manner in which questions were scored and ranked were explained. The highest ranked questions within each subject area, as well as the top 3 ranked questions overall, were identified. Survey questions were regrouped into tiers from broad to finer scales as a "straw dog" to initiate workshop discussion.

State of Knowledge

Ted Armstrong: History, Policy and Recovery Planning Process

A historical view of caribou range, government

policy and regulation, and scientific investigations, including early and recent status reports, was provided. Work in the 1950s noted a decline in caribou range occupancy. Changes in the southern limit of "continuous occupancy" were described. A synopsis of OMNR policy development and differences between NW and NE policy direction and management prescriptions were noted. In the recovery planning process, range was delineated through recorded presence in 10 x 10 km pixels. An overview of the draft provincial Recovery Strategy for Forest-Dwelling Woodland Caribou (developed under the Species at Risk Accord), a draft framework for the management of sympatric cervids, and the developing Caribou Conservation Framework were presented.

Jim Schaefer: Future Demographic Trends

Recent trends in caribou population growth (r) in several jurisdictions (Alberta, Saskatchewan, Ontario, Québec, and Labrador) have been negative, one in Manitoba was positive. Range recession has occurred in eastern North America since the 19th century. The estimated time to extirpation is year 2094 within Ontario (with range breadth of 737 km, $r^2 = 0.989$). The world distribution of latent extinction risk zones (Cardillo et al. 2006) (of which northern Canada/Alaska and eastern Canadian forests are included) was discussed. The decline in caribou range was described relative to climate disruption, wildfire regime change, and invasive species leading to forest landscape composition change (e.g., mountain pine beetle spread).

Ontario Regional Status

Glen Brown: Recent Studies in NE Ontario

Objectives of the work were to determine: population status, patterns of habitat selection and range use, and characterization of late winter and calving habitat. Population growth rates estimated from satellite collar data were: -0.22 (1998-99), -0.11 (1999-2000), and -0.11 (2000-01). Seasonal range size varied significantly among seasons but not years and caribou exhibited large-scale movements between summer and wintering areas. Late winter foraging habitat had higher amounts of terrestrial and arboreal lichens, with lower stand density in used areas (Wilson 2000). The Patchworks forest-harvesting simulation model and a resource selection function were

employed to predict the effects of three forest management strategies on the relative probability of caribou occurrence on a managed forest (Brown 2005). Management strategies that included caribou constraints produced greater probabilities of caribou occurrence than a strategy lacking explicit caribou objectives (existing government guidelines). The strategy with only aspatial habitat supply targets produced relative probabilities of caribou occurrence similar to, or greater than, the strategy containing spatial constraints relevant to caribou. A combination of management targets that reflect the habitat needs and spatial requirements of woodland caribou should be used to guide conservation of caribou populations in boreal forests. A further analysis is in progress to identify potential thresholds in land cover attributes that affect probabilities of seasonal and population range occupancy.

Ted Armstrong: Recent Studies in NW Ontario

A summary of early (1960s) work on range occupancy was presented. Range recession themes pertained to habitat and population isolation, fire, logging and agricultural habitat alteration, and mortality factors (i.e., predators, brain worm, pre-1929 hunting, post-1929 poaching) that collectively contributed to increased mortality rates. Various research and inventory projects have occurred in the region; for example, "Caribou Watch", a reporting program directed primarily at tourism outfitters and clientele, collaring work from 1995-2000, with 34 ARGOS satellite collars on 27 cows and 7 bulls to augment caribou ecology understanding, and the Northern Boreal Initiative 2-stage line-transect survey undertaken to determine caribou distribution and health (% calves) north of current forest harvesting areas. Management studies from 2000-2006, summer habitat use of Lake Nipigon Islands, calving surveys/nursery habitat, establishing a provincial database, and genetic research via faecal pellets are examples of other recent and/or ongoing work. Future U.S.-based studies using historic Slate Island herbivore exclosures for comparison with those on Isle Royale are under development.

Planning

Phil Elkie: Caribou Mosaics

The goal of planning caribou mosaics is to maintain a continuous supply of year-round habitat

distributed spatially and temporally across the landscape to ensure permanent range occupancy. As an example, within the Whiskey Jack Forest, a portion of the Forest Management Unit was assessed using a radius distance of 47.2 km (the average seasonal movement of several radio-collared caribou) or an estimated 700,000 hectares. In creating habitat tracts, the line of continuous occupancy should reflect known range use. If range is observed south of the current "line", that additional area should be included in future treatments. Habitat suitability ranking was delineated by 20-year stand age-classes. Winter refuge habitat was designated as used, useable, or preferred. The percentage of capable (i.e., potential) winter habitat was estimated and used to create potential habitat tracts on relative forest age class and suitability classifications, both north and south of the line of continuous occupancy. Wetland complexes should be considered in tract assignment as caribou use this habitat during calving. Multi-year data sets of pertinent variables (e.g., fire frequency/location, stand age, wetland class, road density) should be used in the creation of potential habitat tracts. If no Forest Resource Inventory data are available, Landsat or provincial land cover data can be used to estimate habitat potential. Each potential tract should be assessed on such attributes as its winter suitability, level of current use, future capability, and level of importance to calving, migration, and refuge. Collectively, this approach provides a long-term plan for provision of habitat.

Bruce Ranta: Future Forest Policy

Ontario's current suite of forest management guides for wildlife habitat management, including the caribou habitat guidelines, are being largely incorporated into two new Guides; a Landscape Guide and a Stand and Site Guide. These two Guides are designed to work for the most part at 2 scales (i.e., landscape and Forest Management Units). However, as implied by the name, the Stand and Site Guide will provide some differentiation at the FMU scale between stand direction and what to do with site specific values. The Landscape Guide will give direction on landscape pattern and structure (e.g., edge, patch size) and forest composition and abundance (landscape area by forest unit and seral stage), and landscape function as habitat. The Landscape Guide will direct landscape mosaics using a



coarse filter approach modified by habitat tract, calving area, wetland location, and water/travel energy expenditures. Both Guides follow an adaptive management approach of developing, implementing, monitoring, and evaluating. The Stand and Site Guide is MNR's interpretation of a fine filter approach – fine filter goals for caribou habitat include: keep silvicultural ground rules and forest cover management consistent with caribou habitat objectives, including maintenance of hardwood and balsam fir < 10%, minimizing edge, encouraging growth and maintenance of arboreal lichens in lowland and riparian areas, avoiding road building in high quality caribou habitat, quickly renewing fine textured soil sites, and restricting harvest periods to ≤ 20 years. Additionally, areas adjacent to wildfires will be harvested and road construction reduced via increased skid distances.

Other Jurisdictions

Vince Crichton: Manitoba - Owl Lake Study Area

The goal of Manitoba's Conservation and Recovery Strategy for Boreal Woodland Caribou is self-sustaining populations via habitat management, while the objectives are to maintain local populations and habitat, reduce threats, understand caribou ecology, enhance outreach and communication, and lastly, restore populations where feasible. Current threats are: habitat loss, fragmentation (through roads), predation, uncontrolled hunting, sensory disturbance, disease, and climate change/wildfire. An advisory committee was founded in 1994 and local committees were formed in the NW and Eastern regions, respectively, comprised of a multi-jurisdictional membership. Regional activities

include: monitoring via collars, identifying key habitats, incorporating range use knowledge in timber harvest plans and hydro developments, developing population estimates, and undertaking genetic analyses through fecal samples.

Under the 2005 Landscape Management Strategy, experimental forestry practices are allowed with the provision that 2/3 of the total winter range is maintained in large contiguous blocks (i.e., 100 km²), there is no degradation of the winter zone, and harvesting is done to develop a suitable harvesting regime. Within the Owl Lake range, caribou are predominately located in 60-69 year-old jack pine stands and treed bogs, of which a portion of that range is being harvested under an experimental harvest design, with habitat retention and natural landscape adjacency. On-going monitoring (e.g., collared animals, mortality causes, alternate prey/predator abundance, and permanent vegetation plots) and assessment will indicate whether the objectives of retaining caribou use and creating future caribou habitat have been achieved. Prescriptions for the area include a large suite of road treatments including access minimization, decommissioning after use (culvert removal, V-plowing, debris spreading), and physical barriers in non-use periods.

Research on 3 other populations was identified (i.e., Naosap seasonal home ranges; Bog, Interlake, and Naosap multi-year DNA fecal sampling). Population structure for 5 areas of the province was also noted, along with interprovincial caribou population movements.

Réhaume Courtois: Québec - First Approaches in Forest Management

The primary causes of range recession of caribou in Québec are thought to be hunting and predation, associated indirectly with habitat modification. Recent observations suggest the presence of a continuous distribution of 2,000-3,000 forest-dwelling caribou north of 49°N and 2 small isolated herds south of the continuous distribution. Large forest-dwelling caribou populations that existed into the 1960-1970s have now disappeared. The best land management strategy is considered to be natural disturbance pattern emulation. Seven harvest guidelines (i.e., delimiting the area used by caribou, delimiting large protection blocks, maintaining inter-block connectivity, concentrating

cuts in large blocks, favouring irregular cut forest structure, using adaptive management, and experimenting with ecosystem management) provide direction for forest harvesting within caribou range. Aerial surveys are used to delineate Areas of Concern (AOC) and create a Forest Management Plan (FMP) in each AOC.

In 2000, the first FMP (2,772 km²) was created on the north shore of the St. Lawrence River. Six protection blocks (508 km²), interconnected with corridors 400m wide (57 km²) were delimited. Small diameter commercial stem retention was favoured in cut blocks and road construction was excluded through protection blocks. The cuts progressed from east to west and north, with the result that caribou moved their most intensive use to areas west and south of the cuts. From 1999 to 2002, aerial surveys indicated a 59% decrease (from 104 to 43 individuals) in caribou numbers in the area subject to the FMP followed by a gradual recovery (≈90 individuals in 2004 and 2005). Telemetry showed that protection blocks were intensively selected by caribou in 1998 and 1999 but their use diminished by ≈ 40% in 2000 and remained relatively stable thereafter. Selection of corridors varied from year to year and cuts remained heavily avoided throughout the study. It was concluded that connectivity between protection blocks and unperturbed conifer forest matrix must be maintained to keep caribou in an AOC subject to forestry activities. Over the short term, the percentage of small stems remaining was not adequate to encourage early re-use of cut areas. Caribou may use cut areas during the summer 15-20 years post-harvest, but not during the winter. Targets for the conifer matrix to be maintained within AOCs and for retention within cut areas were suggested.

Elston Dzus: Alberta - Cumulative Impacts on Caribou

Most of the Alberta landscape is used extensively for human land-uses (both industrial and non-commercial human uses). There is a near complete and overlapping land base allocation to multiple resource users including forestry, oil and gas, and mining. Currently, there is an average linear density of anthropogenic edge of approximately 2 km/km² in the boreal region of Alberta, with the energy sector being the single largest component of "edge" creation, both



currently and projected into the future. Growth is forecasted to occur for most metrics of human land use, with linear density forecast to range from 3 to 8 km/km², depending on the growth and reclamation trajectories chosen. Cumulative effects are hypothesized to be affecting caribou population dynamics.

Provincially, caribou are classified as threatened and are categorized as 2 ecotypes "Boreal" (non-migratory, primarily peatland habitat) and "Mountain" (migratory, primarily forested foothills and alpine/subalpine habitat). Caribou population decline is thought to be multi-causal (e.g., direct and indirect habitat loss and alteration; predation mediated by land use) and is manifested in low recruitment rates. Caribou have been shown to exhibit reduced use of habitat near linear features (roads, seismic lines), well sites, and cutblocks. Wolves, on the other hand, select linear corridors and travel faster when on them. It is hypothesized that predator/prey interactions are thus altered through landscape changes. Access development and management of human (and predator) use of linear features are key aspects of caribou management strategies. Tradeoff analyses and engagement of adaptive management through landscape planning are currently underway under the auspices of the Alberta Caribou Committee (<http://www.albertacariboucommittee.ca/index.htm>).

Drivers

Ian Thompson/Jim Baker (presenter): Climate Change Effects on Caribou Ecology

Climate change could result in two major effects on caribou: loss of habitat and increased energy costs.

Those changes would occur primarily through an altered fire regime, with an increased occurrence and severity of fires. Energy costs would increase as a result of summer heat and increased harassment by insects. Modelling effects of climate change on forest species composition shows a trend towards increased aspen and jack pine, with less old forest, across large parts of the present boreal forest, with some grassland conversions occurring in western Ontario. Caribou are predicted to be restricted to a relatively small portion of northwestern Ontario under a 2xCO₂ scenario. An invasive spread of insects such as mountain pine beetle could further change habitat condition with a cumulative negative impact on caribou.

Darren Sleep: Caribou Research in Ontario: Perspectives from NCASI

The National Council for Air and Stream Improvement (NCASI) is a non-profit environmental research organization that seeks to create credible scientific information required to address the environmental information needs of the forest products industry in North America. NCASI conducts surveys, performs field measurements, undertakes scientific research, and sponsors research by universities and others to document the environmental performance of industry facility operations and forest management, and to gain insight into opportunities for further improvement in meeting sustainability goals. The key focus of NCASI is to support priority research for industry members, with a focus on research associated with information gaps identified post-analysis of the existing body of Canadian research. NCASI's Forestry Technical Studies Program includes aspects of wildlife and biodiversity, watershed management, and conservation planning. Within the first area of research, NCASI undertakes research on species at risk relevant to the forest products sector. In 2004, NCASI published Technical Bulletin No. 893, *Ecological interactions among caribou, moose and wolves: literature review*. This review, while documenting the substantial body of evidence for altered habitat effects on predator dynamics, identified a range of information gaps, including a lack of empirical evidence of a causal relationship between forest management and altered predator dynamics, a need for longer-term and experimental work on altering ungulate and/or wolf populations, a lack

of information on caribou nutritional requirements, and a lack of studies on the effects of silvicultural activities on caribou reproduction and resilience. A subsequent report, tentatively titled, *A review of the effects of seasonal diet on woodland caribou population dynamics*, is due to be released in 2007. This report reviews the current literature on caribou nutrition, documents the need for an increased understanding of caribou nutritional requirements, suggests that a greater amount of caribou research should monitor variables beyond caribou numbers or range dynamics, suggests that little is known about the effects of alternate predators (e.g., black bears), and highlights the need for studies of the effects of industrial harvesting on caribou foraging behaviour, movement rates, and energy balance. Current work by NCASI includes undertaking an overview of current caribou research efforts in Canada, which will enable the identification of opportunities to partner with universities and researchers to further knowledge of caribou dynamics as they relate to the forest industry.

Gillian McEachern: Social - ENGO Concerns/Drivers and Policy Concerns

What is past research showing? What is the government policy response? What are the priorities? The research indicates that there is a need for large areas free of industrial activity. It is estimated that within Ontario, caribou have been extirpated from 50% of their former range, with no evidence of them returning to areas of post-industrial activity. Ontario forestry guidelines are considered a "best example" only, but consider an inadequate spatial scale and are based on

mitigating the impact of the current harvest intensity. Ontario lacks a comprehensive road planning mechanism, as well as any form of cumulative effect mitigation stemming from the various resource sectors. The draft provincial Recovery Strategy lacks immediate actions. The province needs to apply a precautionary approach, map critical habitat, and focus on what area(s) should be left out of industrial activity rather than mitigating current industrial intensity. Additionally, Ontario needs to define the threshold of disturbance and apply adaptive management to its guidelines approach.

Analysis

Tom Nudds: Decision Analysis and Adaptive Management for Caribou in Ontario

Past relationships among science, policy, and management were described as "muddling through" or "learning *then* doing". In contrast, Adaptive Management is "learning *while* doing". The importance of policy as hypothesis and management by experiment was recognized. The integration of Adaptive Management with Decision Analysis and the 10 steps to successful DAAM (Table 3, Appendix C) were described. The Crown Forest Sustainability Act (CFSA 1994) was recognized as providing the over-arching policy/hypothesis, namely that "... *the health and vigour of Crown forests should be provided for by using forest practices that, within the limits of silvicultural requirements, emulate natural disturbances and landscape patterns, while minimizing adverse effects on ... social and economic values, including*

Table 3. Steps required to complete an inclusive Decision Analysis and Adaptive Management (DAAM) program (Jones and Nudds 2003) for forest-dwelling woodland caribou in Ontario.

Step	Description
1	All concerned parties should be involved
2	Inclusive specification of management objectives and options
3	Identification of critical uncertainties, as hypotheses
4	Critical, rigorous examination of evidence for alternative hypotheses
5	Development of models to forecast outcomes, given different hypotheses
6	Evaluation and ranking of competing hypotheses by likelihood in light of uncertainty (DA)
7	Evaluation of experimental management options (DA)
8	Design and implement management experiments according to sound experimental design principles (AM)
9	Monitor key responses (AM)
10	Update ranking of competing hypotheses by likelihood given monitoring results (DAAM)



recreational and heritage values." Thus, the CFSA suggests that forest practices are allowed to the extent that they do not adversely affect caribou. With regard to DAAM for caribou in Ontario, the first 2 steps have already been completed. Among these was a synthesis of key sources of uncertainty about factors affecting caribou persistence deriving from broad stakeholder consultation and input to the CNFER survey. A continuation of the DAAM process in this workshop should lead to the development of competing models of those factors, and to preliminary designs for data acquisition to test among them, to evaluate the extent to which timber management is consistent with the policy/hypothesis of natural disturbance emulation.

RESEARCH DEVELOPMENT

Excluding the workshop facilitator, Tom Nudds, and workshop organizer, Ed Iwachewski, the remaining 30 participants were divided into 4 groups (Appendix B) based on their area of expertise, non-government representation, and geographic origins, with a mix of academic scientists, OMNR research scientists and specialists, industry and environmental scientists and representatives, each group with a designated leader/reporter.

Beginning with the identification of critical uncertainties as hypotheses (Step 3), each group worked sequentially through the remaining steps needed to complete an inclusive DAAM program (Table 3, Appendix C) for forest-dwelling woodland caribou in Ontario. Each group began by identifying dependent variables (i.e., "what we want

to know") and assessing whether data were currently available or could be obtained. Next, the groups identified independent/predictor variables that may be associated with the dependent variables (i.e., "what we can measure") and again assessed whether or not data were currently available or could be obtained. Once all background material was assembled, each group used the information to create competing word models/hypotheses that would accommodate the key uncertainties (predictor variables).

At each stage, group leaders reported back to plenary for further discussion of results, particularly the key word model(s) developed. Groups were then asked to assign "degrees of belief" (prior probabilities) and rank competing word models/hypotheses based on the adequacy of each model as a description of the "real" world and the quality of available/attainable data for estimation by each of 3 experimental management options: model simulation, retrospective analysis, and field experiments. The spatial and temporal scales required to evaluate the word models/hypotheses were assessed and the type of Adaptive Management corresponding to alternative experimental designs was determined. Lastly, the facilitator, Tom Nudds, summarized the results of the working group discussions in the context of the 10 steps needed to complete an inclusive DAAM program for forest-dwelling woodland caribou in Ontario and assessed whether participants had successfully addressed the 3 most important caribou research issues identified in the CNFER survey.



Dependent Variables

In total, 22 dependent variables were identified by the working groups (Table 4). The number of dependent variables identified varied by group, ranging from 4 to 15. The (finite) rate of population increase per individual per unit time (λ) and probability of occurrence were identified by all groups, while the probability of persistence and population size (N) were noted by 3 groups. Recruitment, per capita (instantaneous) rate of population growth (r), probability of occupancy, movement, age-specific survival, and condition were identified by 2 groups. The remaining dependent variables were each identified by one group.

Independent Variables

The 4 working groups identified 44 independent variables (Table 5), which were categorized by land-use (9 variables), predation (9), habitat pattern (21), parasites and disease (2), and weather and climate (3). In the land-use category, groups identified "amount and distribution of linear features" and "linear feature human activity" most frequently ($n=3$) as independent variables. "Moose density", "deer density", "predation rate", "illegal harvest", and "subsistence harvest" were the variables most often identified by groups ($n=3$) in the predation category. Although numerous habitat pattern variables were identified, only "landscape pattern" was identified by all 4 working groups; "forest cover type/age class composition, disturbance origin and pattern" was identified by 3 groups.

Table 4. Dependent variables identified by working groups in the development of a research program for forest-dwelling woodland caribou in Ontario.

Dependent Variable	Working Group ^a			
	A	B	C	D
Age-specific fecundity			x	
Age-specific immigration and emigration			x	
Age-specific survival		x	x	
Calf survival				x
Condition			x	x
Demography				x
Density			x	
Diet composition			x	
Fidelity				x
Finite rate of population increase (λ) ^b	x	x	x	x
Genetic similarity			x	
Habitat suitability		x		
Home range size				x
Instantaneous rate of population increase (r)		x	x	
Isolation			x	
Movement			x	x
Population size (N) ^b	x	x	x	
Probability of occupancy			x	x
Probability of occurrence ^b	x	x	x	x
Probability of persistence ^b	x	x	x	
Recruitment		x		x
Survival		x		
Total	4	9	15	10

^a Leaders and members of each working group are listed in Appendix B.

^b Dependent variables identified by 3 or more groups

Table 5. Independent variables identified by working groups in the development of a research program for forest-dwelling woodland caribou in Ontario.

Independent Variable Category	Independent Variable	Working Group ^a			
		A	B	C	D
LAND USE	Amount and distribution of linear features (e.g., roads, RR's, trails, ROW's) ^b	x	x		x
	Amount and distribution of non-linear features (e.g., cut blocks)	x			
	Anthropogenic edge (combined: cut blocks, roads, ROW's, RR's, trails)	x			
	Linear feature construction impacts (e.g., gravel ridge extraction)		x		
	Linear feature human activity ^b	x	x		x
	Non-linear human activity	x			x
	Road density (e.g., forestry, mining, highways and winter roads)		x	x	
	Seasonal human recreational/activity (e.g., calving sites/walleye anglers)	x			x
	Sensory disturbance			x	
PREDATION	Aversive conditioning of predators		x		
	Beaver Density		x		x
	Deer density ^b		x	x	x
	Illegal harvest ^b	x		x	x
	Moose density ^b		x	x	x
	Predation rate (bear, wolf, wolverine) ^b	x		x	x
	Predator density (bear, wolf, wolverine)		x	x	
	Prey biomass (caribou, moose, deer, beaver)	x			
	Subsistence harvest ^b	x		x	x
HABITAT PATTERN	% area with cutover disturbance		x	x	
	% area with fire disturbance		x		
	% area with old growth		x		
	Calving habitat (i.e., islands, peninsulas, treed fen/bog/peat land islands)		x		
	Emulated natural disturbance area and pattern			x	x
	Fire risk	x			
	Fire suppression	x			
	Forest cover type/age class composition, disturbance origin and pattern ^b	x		x	x
	Habitat area and connectivity		x	x	
	Landscape pattern (e.g., edge, interspersed, patch size) ^b	x	x	x	x
	Late winter cover (e.g., conifer)		x		
	Lichen density			x	
	Lichen woodlands		x		
	Mosaic blocks and non-mosaic areas (i.e., protected areas)		x		
	Natural disturbance (e.g., fire/blow down) area and pattern			x	x
	Open canopy with and without lichen		x		
	Ridge habitat		x		
	Seasonal habitat characteristics	x			
	Silvicultural regime				x
	Soil type/profiles			x	x
	Stand structure (e.g., vertical)			x	
PARASITES and DISEASE	Disease (e.g., <i>P. tenuis</i> , warble fly, tabanids, <i>F. magna</i>)	x			x
	Insects (e.g., behavioural/nutritional stress)	x			x
WEATHER and CLIMATE	Climate	x	x		
	Snow (e.g., crusting, depth, duration/timing, break/freeze up, stochasticity)				x
	Winter severity			x	

^a Leaders and members of each working group are listed in Appendix B.^b Independent variables identified by 3 or more groups.

Data Availability

Collectively, working groups assessed the availability of 24 different data types for 3 research designs (Table 6): model simulation, retrospective analysis, and field experiments. The likelihood of attaining sufficient data was greatest (22/24) with the experimental approach (Table 7) and lowest (7/24) for retrospective analyses. Many data types necessary for model simulations had a high likelihood (16/24) of attainability.

Word Models/Hypotheses

A total of 12 word models/hypotheses were developed by the 4 working groups (Table 8). Group A created 6 models, of which the least parsimonious ranked highest within that group. Group B created one model with several nested independent variables. Group C created one model, which was among the most parsimonious presented by all groups. Group D arrived at 4 distinct models, varying (similar to Group A) in the number of independent variables invoked within each model.

Table 6. Estimated current availability and/or attainability of sufficient data required for 3 research designs in the development of a research program for forest-dwelling woodland caribou in Ontario.

Data Type	Research Design					
	Model Simulation		Retrospective		Field Experiment	
	Current	Attainable	Current	Attainable	Current	Attainable
Anthropogenic disturbance (all inclusive)	Yes	Yes	Yes	Yes	Yes	Yes
Caribou habitat	Yes	Yes	Yes	Yes	Yes	Yes
Condition	Some	Yes	Some	Yes/? *	Some	Yes
Density	?	?	?	?	?	Yes/?
Diet composition	Some	Yes	Some	?	Some	Yes
Finite rate of population increase (λ)	Estimates	Yes	Some	Yes/?	Some	Yes
Forest < 50 years	Yes	Yes	Yes	Yes	Yes	Yes
Genetic similarity	Some	Yes	?	?	Yes	Yes
Human activity	Yes	Yes	Yes/?	Yes/?	No	Yes
Human harvest of caribou	Yes/?	Yes	Yes/?	Yes/?	No	Yes
Isolation	No	Yes	No	?	No	Yes
Movement	Some	Yes	Some	Yes/?	Some	Yes
Natural disturbance	Yes	Yes	Yes	Yes	Yes	Yes
Number (range population estimates)	Estimates	?	?	?	?	Yes/?
Occurrence	Yes	Yes	Yes	Yes/?	Some	Yes
Persistence	Yes	Yes	?	Yes/?	No	Yes
Precipitation (e.g., snow parameters)	Yes/?	Yes/?	Yes/?	Yes/?	Yes/?	Yes
Predation rate	No	No	No	No	?	Yes
Prey biomass (beaver)	Yes/?	Yes/?	Yes	Yes	Yes	Yes
Prey biomass (caribou)	?	Yes/?	Yes	?	?	Yes
Prey biomass (deer)	?	Yes/?	Yes/?	Yes/?	?	Yes
Prey biomass (moose)	Yes/?	Yes/?	Yes	Yes	?	Yes
Range occupancy	Yes	Yes	Yes	Yes/?	No	Yes
Roads	Yes	Yes	Yes	Yes	Yes	Yes

* ? indicates uncertainty that sufficient data are currently available or can be attained.

Table 7. Estimated likelihood of data availability and/or attainability for 3 research designs in the development of a research program for forest-dwelling woodland caribou in Ontario.

Likelihood	Research Design					
	Model Simulation		Retrospective		Field Experiment	
	Current	Attainable	Current	Attainable	Current	Attainable
Yes	9	16	10	7	7	22
Yes/? ^a	4	5	4	10	1	2
Estimates	2	0	0	0	0	0
Some	4	0	4	0	5	0
?	3	2	4	6	6	0
No	2	1	2	1	5	0
TOTAL	24	24	24	24	24	24

^a ? indicates uncertainty that sufficient data are currently available or can be attained.

Table 8. Competing word models/hypotheses suggested by working groups in the development of a research program for forest-dwelling woodland caribou in Ontario

Working Group ^a	Model #	Word Model
A	1	Probability of occurrence = f (predation rate/prey biomass + caribou habitat + roads + natural disturbance + anthropogenic disturbance) ^b
	2	Probability of occurrence = f (forest < 50 years + open road)
	3	Probability of occurrence = f (prey biomass + anthropogenic edge)
	4	Probability of occurrence = f (prey biomass + human activity on linear features + non-linear edge)
	5	Probability of occurrence = f (predation rate + open roads + non-linear cut blocks)
	6	Probability of occurrence = f (predation rate + human harvest)
B	7	λ . Probability (occurrence, persistence), Recruitment, Survival = f (habitat [species composition, stand structure, cutting, fire, configuration {fragmentation, connectivity}] + predators [density and alternate ungulate prey density] + roads [density and use intensity] + <i>P. tenuis</i>) ^c
C	8	Probability of persistence, Recruitment = f (predation, landscape pattern, stand structure) ^d
D	9	λ . Probability of occurrence, Avoidance, = f (wolves [numerical, functional] + 2 ⁰ roads + wolves X roads)
	10	λ = f (roads + wolves/numerical + bears/numerical + alternate prey/numerical)
	11	Probability of occurrence = f (forest composition + disturbance + wolves/functional + bears/functional + alternate prey)
	12	Probability of occurrence in winter = f (wolves/numerical + alternate prey/numerical + snow + forest composition + tabanids + sensory disturbance + <i>P. tenuis</i>)

^a Leaders and members of each working group are listed in Appendix B.

^b Top ranked model within working group A. Other working groups did not rank competing word models.

^c Includes regional co-variables by caribou ecotype (i.e., forest-dwelling, forest-tundra) and/or ecoregion and east versus west versus north.

^d Implicit belief that landscape pattern is linked to alternate prey density/predator effect size.



Content Analysis of Word Models/Hypotheses

The range of dependent variables used in the models varied across groups. Group A solely selected probability of occurrence. Group B selected several dependent variables including the (finite) rate of population increase per individual per unit time (λ), probability of occurrence, probability of persistence, recruitment, and survival. Group C chose probability of persistence and recruitment. Group D provided several word models with different dependent variables, including the finite rate of population increase (λ), probability of occurrence, avoidance, and probability of occurrence in winter. Collectively, probability of occurrence was noted most frequently ($n=9$; but note that group A selected the variable 6 times), followed by the finite rate of population increase ($n=3$), and probability of persistence or recruitment ($n=2$); avoidance, survival, and probability of occurrence (winter) were each noted once.

Independent variables within the Land Use, Predation, and Habitat Pattern categories were those most frequently used within the suggested word models/hypotheses (Table 9). Although there was variation among working groups regarding the specific independent variables invoked, all working groups selected at least one road-related, predation, and habitat variable.

Thus, a general word model/hypothesis, reflective of the collective variables used across all groups, that could be used in the development of a

research program for woodland caribou in Ontario is: ***the probability of forest-dwelling woodland caribou occurrence = f (roads [density/use/type] + predation [density/rate/prey biomass or abundance] + multi-scale habitat pattern).***

Experimental Management Options and Design

Consideration was given to the spatial and temporal scales required to evaluate the word models/hypotheses under each of 3 experimental management options: model simulation, retrospective analysis, and field experiments. Working groups then used a dichotomous key (below) provided by Tom Nudds to determine the type of Adaptive Management corresponding to selected experimental designs.

Key to Types of Adaptive Management

1. **Deliberate attempt to evaluate policy?**
 Yes.....Adaptive management; go to 2.
 No.....Reactive management.
2. **Alternative policies evaluated/compared?**
 Yes.....Active adaptive management (AAM);
 go to 3.
 No.....Passive adaptive management (PAM).
3. **Evaluations/comparisons are designed?**
 Yes.....Manipulative experimental AAM;
 go to 4.
 No.....Mensurative "experimental" AAM.
4. **Evaluations use spatial/temporal controls?**
 Yes.....AAM with treatments and controls,
 baselines, etc.
 No.....AAM with modelling, prior probabilities
 and Bayesian inference/model selection.

Two groups discussed and arrived at a decision on the temporal scale of experiments (Table 10). Up to a 10-fold time difference (i.e., 5 to 50 years) was envisioned, dependent upon the experimental design employed. Spatially, 3 groups chose a multi-spatial scale design, while Group D suggested a landscape level treatment design. Group A felt that all 3 experimental management options could be used. All groups recommended an Active Adaptive Management experimental design with controls.

Table 9. Content analysis of independent variables used in word models/hypotheses suggested by working groups in the development of a research program for forest-dwelling woodland caribou in Ontario.

Independent Variable Category	Independent Variable	Frequency of Independent Variable Use by Working Group ^a				Variable Total	Variable Category Total
		A	B	C	D		
LAND USE	Anthropogenic disturbance	1				1	12
	Anthropogenic edge	1				1	
	Linear feature human activity	1				1	
	Non-linear cut blocks	1				1	
	Open roads	2 ^b				2	
	Road density		1			1	
	Road use intensity		1			1	
	Roads	1			1	2	
	Secondary roads				1	1	
	Sensory disturbance				1	1	
PREDATION	Alternate prey				1	1	20
	Alternate prey/numerical				2	2	
	Alternate ungulate prey density		1			1	
	Bears/functional				1	1	
	Bears/numerical				1	1	
	Human harvest	1				1	
	Predation			1		1	
	Predation rate	3				3	
	Predator density		1			1	
	Prey biomass	3				3	
	Wolves (numerical/functional)				1	1	
	Wolves x roads				1	1	
	Wolves/functional				1	1	
	Wolves/numerical				2	2	
HABITAT PATTERN	Caribou habitat	1				1	16
	Configuration		1			1	
	Connectivity		1			1	
	Cutting		1			1	
	Disturbance				1	1	
	Fire		1			1	
	Forest < 50 years	1				1	
	Forest composition				2	2	
	Fragmentation		1			1	
	Landscape pattern			1		1	
	Natural disturbance	1				1	
	Non-linear edge	1				1	
	Species composition (i.e., plant)		1			1	
	Stand structure		1	1		2	
PARASITES and DISEASE	<i>P. tenuis</i>		1		1	2	3
	Tabanids				1	1	
WEATHER and CLIMATE	Snow				1	1	1

^a Leaders and members of each working group are listed in Appendix B.^b Variables in bold type were the most frequently selected by the working group within a variable category.

Table 10. Spatial and temporal dimensions of experimental management options and type of Adaptive Management recommended for evaluation of word models/hypotheses suggested by working groups in the development of a research program for forest-dwelling woodland caribou in Ontario.

Working Group ^a	Research Design Dimensions		Type of Adaptive Management
	Temporal (years)	Spatial (Grain/Extent)	
A	Up to 50 ^b	Multi-scale (research design/data dependent)/10,000 km ²	Simulation + Retrospective + Active (with controls)
B	5-10	Multi-scale/3,000-10,000km ²	Active (with controls)
C	Not discussed	Multi-scale/pixels	Active (with controls)
D	Discussed/no final decision	Modelled as uncertainty ^c /Landscape scale (40,000 km ² reference area/40,000 km ² pre-disturbed treatment area/80,000 km ² post-disturbed treatment area)	Active (with controls)

^a Leaders and members of each working group are listed in Appendix B.

^b Time required to observe a response in caribou use.

^c Scale included as an independent variable.

SUMMARY AND NEXT STEPS

A key element of the CNFER Forest-dwelling Woodland Caribou Research Workshop was the acceptance of policy as hypothesis and the need for management by experiment (Lancia et al. 1996). Adaptive management provides a process to evaluate the effectiveness of policy in achieving an objective. This approach would allow determination of the effectiveness of emulating natural disturbance patterns through forest practices, as embodied by CFSA (1994) and related policy, in meeting the objective of keeping forest-dwelling woodland caribou on the Ontario landscape.

To evaluate the extent to which forest practices conducted under a policy of natural disturbance emulation might achieve the objective of sustaining woodland caribou, key uncertainties need to be expressed as competing models. Generally, participants in the CNFER workshop agreed that the probability of forest-dwelling woodland caribou occurrence was likely to be some function of roads (density, use and/or type), predation (predator density, predation rate, and prey biomass or abundance, including alternative prey), and habitat pattern (disturbance type, composition, and patch size) at multiple spatial scales; i.e., **the probability of forest-dwelling woodland caribou occurrence = f (roads [density/use/**

type] + predation [density/rate/prey biomass or abundance] + multi-scale habitat pattern).

The following two basic models can be derived from the general word model/hypothesis to express the degree to which past and present forest practices are consistent with the policy to emulate natural disturbance. The more parsimonious (simple) model is:

$$\text{Prob (caribou occurrence)} = f(\text{roads [density/use/type] + predation [density/rate/prey biomass or abundance] + habitat [composition/patch size]}) \quad (1)$$

If this model provides a good fit to data on the probability of caribou occurrence – that is, knowledge of the type of disturbance from which the landscape regenerates is not required to explain caribou distribution – then the policy objective to emulate natural disturbance as a means of facilitating caribou persistence is achieved.

On the other hand, a more complex model that includes knowledge of disturbance type may be proposed to improve predictability:

$$\text{Prob (caribou occurrence)} = f(\text{roads [density/use/type] + predation [density/rate/prey biomass or abundance] + habitat [disturbance type/composition/patch size]}) \quad (2)$$

If model (2) provides a better fit to data on the probability of caribou occurrence than model (1), then knowledge of the type of disturbance from which landscapes regenerate is required. That is, there is something different between landscapes originating from timber harvest and fire that must be understood to better explain caribou distribution. If this is the case, then the policy objective to emulate natural disturbance to facilitate caribou persistence has not been achieved. In this event, future adjustments to forest practices would need to be made to bring results in line with the objective of sustaining caribou on the landscape – that is, model (1) is restored as the superior model of caribou distribution – thereby completing an adaptive management cycle.

A recent analysis by Vors et al. (2007) is consistent with model (2), nevertheless, workshop participants identified other key uncertainties not addressed by that analysis. The variables identified as important in the CNFER workshop models could form the starting point for further model development and evaluation through an adaptive management process. These further models should explore potential interactions between landscape origin and configuration, linear features, and other surrogates for the effects of human and other predators on caribou populations.

The steps above would complete a retrospective analysis of the extent to which past and present forest management practices emulate natural disturbance. To continuously learn to adjust to changing environments, the set of competing models should be periodically re-evaluated at multiple spatial scales every 5 years, consistent with an experimental (i.e., Active Adaptive Management) approach. In contrasting the two models presented above, for example, caribou occurrence could be compared (monitored) on: (1) landscapes with natural fire disturbance only (control); (2) landscapes where the new forest management guides have been implemented to achieve the CFSA policy objective of keeping forest-dwelling woodland caribou on the Ontario landscape (treatment 1); and (3) landscapes harvested with historical guidelines (treatment 2). The temporal scale necessary to monitor key responses may range from 5 to 50 years.

This policy-testing framework can be generalized

to include a wide range of performance measures (Table 4) and potential variables affecting the sustainability of caribou populations (Table 5) under a variety of threats (e.g., mineral extraction, petroleum exploration) across the boreal forest. In particular, it provides a robust framework for guiding efficient effectiveness monitoring within an inclusive Decision Analysis and Adaptive Management program.

DAAM Steps Completed for Forest-dwelling Woodland Caribou in Ontario

The workshop adhered to the 10 steps required to complete an inclusive Decision Analysis and Adaptive Management (DAAM) program (Appendix C). The following is a summary of the process and collective progress toward the completion of an inclusive DAAM program for forest-dwelling woodland caribou in Ontario prior to and during the workshop:

Step 1: *All concerned parties should be involved.* CNFER completed this step by developing a comprehensive survey of stakeholder groups within provincial and federal governmental jurisdictions, academia, industry, and "consumptive" and "non-consumptive" non-governmental organizations, reaching a total of 262 individuals across the province that had a demonstrated interest in caribou.

Step 2: *Inclusive specification of management objectives and options.* This step was dealt with at the federal and provincial legislative and policy level through specific requirements within the Species at Risk Act (federal), the Endangered Species Act (provincial), the Crown Forest Sustainability Act (provincial), the Ontario Biodiversity Strategy, and OMNR Science Strategy.

Step 3: *Identification of critical uncertainties, as hypotheses.* Uncertainties were discussed and listed by the 4 independent working groups during the workshop.

Step 4: *Critical, rigorous examination of evidence for alternative hypotheses.* The 4 groups examined data availability and relevance to hypothesis development.

Step 5: *Development of models to forecast outcomes, given different hypotheses.* Multiple word models/hypotheses were developed by each of the 4 groups during the workshop.

Step 6: *Evaluation and ranking of competing hypotheses by likelihood in light of uncertainty (DA).* Two working groups ranked alternate word hypotheses by likelihood and two groups left alternate hypotheses unranked. During the full group session, all hypotheses were presented and discussed.

Step 7: *Evaluation of experimental management options (DA).* These were discussed in the 4 working groups and subsequently in full session. Consideration was given to the spatial and temporal scales required to evaluate the word models/hypotheses under each of 3 experimental management options: model simulation, retrospective analysis, and field experiments.

DAAM Steps Remaining for Forest-dwelling Woodland Caribou in Ontario

Step 8: *Design and implementation of management experiments according to sound principles of experimental design (AM).* Working groups determined the types of Adaptive Management corresponding to proposed experimental designs. All groups recommended an Active Adaptive Management experimental design with controls. Further details of the experimental design (e.g., treatments, replicates) need to be determined before implementation of management experiments can proceed.

Step 9: *Monitor key responses (AM).* Yet to be done.

Step 10: *Update ranking of competing hypotheses by likelihood given monitoring results (DAAM).* Yet to be done.

Caribou Research Issues Identified in the CNFER Survey

The 3 most important caribou research issues identified in the CNFER - Forest-Dwelling Woodland Caribou Research Survey were all related to the effects of disturbance (e.g., by

commercial forestry operations) on the occurrence of forest-dwelling woodland caribou in Ontario. Habitat selection at multiple scales and predation were clearly identified as important factors in the most highly ranked caribou research issue, and road and other corridor effects were among the most important subject areas identified for further research. The general word models/hypotheses on which to found an adaptive management program, identified during this workshop, address all of these concerns. Participants concluded that the probability of occurrence of forest-dwelling woodland caribou is likely to be a scale-variant function of some combination of roads, predation, and habitat structure and composition that needs to be evaluated using Active Adaptive Management.

Next Steps

Having determined general word models/hypotheses, the next steps in developing an adaptive management program for forest-dwelling woodland caribou in Ontario will be to further refine the general models into a subset of competing models, provide details of the experimental design (e.g., treatments, replicates), and identify potential study areas. This will likely be achieved through an experimental design workshop involving a subset of participants with expertise in experimental design who attended the CNFER Forest-dwelling Woodland Caribou Research Workshop. Notwithstanding recent work on habitat modelling (Pearce and Eccles 2004, Brown 2005) and retrospective analyses (Schaefer 2003, Vors et al. 2007), these experimental options should be pursued to improve our understanding of short-term critical data needs and to explore alternative experimental designs to achieve the most efficient design for a long-term adaptive management program.

An adaptive management program for forest-dwelling woodland caribou in Ontario will be a major logistical undertaking, both administratively and financially. There is much room for collaborative core and linked research, and CNFER will continue to pursue potential partnerships with provincial and federal government and non-governmental organizations and individuals, including First Nations, university academics, industry representatives, and environmental groups.

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APPENDICES

Appendix A. CNFER Forest-Dwelling Woodland Caribou Research Survey Results.

Background

In January-February 2006, the CNFER Forest-Dwelling Woodland Caribou Research Survey was sent to Ontario Ministry of Natural Resources (OMNR) managers and staff, industry, non-governmental groups, academic, tourism, federal, and municipal government representatives known to have had involvement or interest in woodland caribou through work on, Forest Management Plans, Protected Areas, Species at Risk, policy development, wildlife management, conservation issues, or research. Survey participants were asked to: rate the importance of conducting forest-dwelling woodland caribou research in each of 9 subject areas, then rank the importance of conducting forest-dwelling woodland caribou research on specific research questions related to each subject area, and lastly to identify the 3 most important specific research questions that they would like to see addressed by a research program at CNFER.

Original Instructions to Respondents

Thank you for your willingness to help shape the forest-dwelling woodland caribou research program at CNFER. On the following pages you are asked to rate and rank the importance of general and specific research questions. Woodland caribou research questions from numerous sources were consolidated, and an initial series of questions that can feasibly be addressed through a CNFER-based research program have been identified and placed in the questionnaire below. Questions are grouped in **Subject Areas** which have been taken and modified from, the April 1999 Workshop, **Planning the Next Round of Caribou Habitat Research**, compiled by K.M. Brown, the **Draft Recovery Strategy for Forest-Dwelling Woodland Caribou (*Rangifer tarandus caribou*) in Ontario**, ed. W.J. Rettie February 3 2005, and from an initial research question summary by B. Allison and L. Eddy at CNFER.

Should you wish to view the initial partitioning of all potential research questions and the sources from which these questions were drawn see the attached Excel work book. Questions judged feasible for CNFER-based research are highlighted in 'green', (Sheet 1), those that require attention, are already proposed, ongoing, or that include past research are highlighted in either blue or red (Sheet 2). Blue highlighting indicates questions that may be answered in synergy with more heavily weighted green-coded research topics. Red-coded research questions are those considered infeasible and those already undertaken or the responsibility of other OMNR sections and university/industry partners – ***in no way are these questions less urgent or important.***

Once completed please return the survey and any comments you wish to add via e-mail to: keith.wade@mnr.gov.on.ca, or by fax if you wish to print the survey to: Centre for Northern Forest Ecosystem Research, Attention of: Keith Wade, (807) 343-4001 or via regular mail to: CNFER (Attn: Keith Wade), 955 Oliver Rd., Thunder Bay, ON, P7B 5E1

Questionnaire Response

RESPONDENTS	NUMBER OF SURVEYS SENT	ANTICIPATED NUMBER OF RESPONSES *	NUMBER RESPONDING	RESPONSE RATE (%)
OMNR	165	104	63	60.6
External	97	56	28	50

* The survey was sent to many OMNR Managers and Non-managers, as well as individuals in external organizations, as an "information item" and they were not expected to respond but were asked to forward the survey to those in their workplace who may be interested in completing it.

Questionnaire Results

1. The importance of conducting forest-dwelling woodland caribou research according to subject areas.

RESEARCH AREA	SCORE ^a
Forest management regimes (FMPs); disturbance & techniques	419.5
Land use planning / policy and management	403
Road and other corridor effects	398
Population management, dynamics and status, ecological dynamics	393
Recruitment, survival, mortality, population limiting factors, cumulative impacts	386
Habitat: critical and core; forage, distribution and fire	368
Inventory, monitoring and reporting	363
Predator/prey dynamics	349.5
Genetics/DNA & metapopulations	264.5

^a Sum of the ranks (1 – 5) for each subject area, where ranks were assigned as follows: 5=Very Important, 4=Important, 3=Somewhat Important, 2=Possibly Important, 1=Not at all Important.

2. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Population Management, Dynamics and Status, Ecological Dynamics*.

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
179	Determine the mechanisms driving forest woodland caribou population dynamics in modified landscapes.	A
97	Determine the interactions between caribou occurrence and density.	B

^a Sum of the inverted ranks (1 or 2) for each question.

3. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Land Use Planning/ Policy and Management*.

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
165	Evaluate effects of landscape disturbances created by commercial forestry operations on caribou populations (via individual caribou survival and mortality causes, recruitment, habitat selection at multiple scales, measuring changing abundance of moose, deer and predation by wolves and bears).	C
115	Investigate the effectiveness of forest management, tourism and other resource and land use planning guidelines in conserving caribou habitat and populations.	D

^a Sum of the inverted ranks (1 or 2) for each question.

4. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Habitat: Critical and Core; Forage Biomass, Distribution; Fire Effects.*

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
515	Determine how caribou use their habitat. (During range recession/population decline are they abandoning poorest habitat first, or avoiding the agent of decline?); (Are stable populations using the entire prime habitat available or only a portion?).	H
508	What are the requisite components of caribou habitat (what is critical habitat)?	G
457	What is the relationship between core habitat size and caribou use?	F
392	What are the interactions among caribou habitat dynamics and habitat selection?	E
280	Does caribou winter habitat quality improve as it gets older (100-120 yrs.) and then gradually decline in value?	J
241	As deep and moderate deep soil upland and winter habitat tracts age do they become less suitable for refuge because of increased hardwood and shrub growth and a shift from lichen to feather moss ground cover?	K
203	What effects does snow cover have on caribou behaviour? Which habitats do caribou prefer during snow cover seasons, and where are these habitats in the landscape?	I

^a Sum of the inverted ranks (1 – 7) for each question.

5. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Forest Management Regimes (FMPs), Disturbance and Forestry Techniques.*

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
841	At what level of disturbance do caribou abandon previously occupied habitat (threshold of disturbance)?	L
698. 5	Examine the recovery of habitat from silvicultural interventions. Is it possible to shorten the recovery time? Can habitat be re-established in 40 yrs.; and how long after regeneration do caribou resume using an area?	M
650	What is the threshold range of fragmentation that is acceptable?	V
631. 5	Can silvicultural practices effectively create caribou habitat?	N
567	What are the effects of large cut and leave blocks on caribou?	Q
538	What is the minimum size of cut blocks that can be used without fragmenting caribou habitat?	S
459	Do caribou attempt to return to areas of habitat disturbed by fire or logging and shift to alternate areas over time?	T
424	Do young intensively managed forests have a structure that will support caribou in winter?	O
407	What is the proportion of good habitat impacted by logging? (Determine caribou use of sites before and after logging).	U
374	What are the effects of light vs. heavy residual stand density?	R
354	What are the effects of increased open areas on caribou?	P

^a Sum of the inverted ranks (1 – 11) for each question.

6. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Predator/Prey Dynamics*.

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
770	At what spatial threshold does commercial forestry begin to alter the interrelationships of caribou, moose, wolves, bears, and wolverines?	W
665	What are the interactions of forest landscapes, densities of other ungulates and predation?	X
558	What is the interaction between human disturbance and predation?	EE
539	Do predators limit caribou populations?	AA
526	What is the response of predators (numbers and behaviour) to disturbance?	DD
520	What are the effects of altered predator prey relationships?	Y
506	Do caribou encountering predators move large distances to known or unknown alternate habitats?	BB
489	Do woodland caribou occur at low densities in balance with predators and other prey species?	Z
441	What is the effect and magnitude of bear predation on caribou in general and along shorelines in particular?	CC
429	Are large areas of older conifer dominated and low diversity forest avoided by predators in winter and summer, possibly as a result of lower hunting success?	GG
315	What might constitute a barrier to wolf movement?	FF

^a Sum of the inverted ranks (1 – 11) for each question.

7. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Recruitment, Survival, Mortality, Population Limiting Factors, Cumulative Impacts*.

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
147	What are the factors that affect the success of calving on islands and shorelines and would reserves be necessary with buffers to minimize the impacts of predators and humans; at what size?	HH
131	Clarify and quantify threats and biologically limiting factors, including climate change effects.	II

^a Sum of the inverted ranks (1 or 2) for each question.

8. The importance of conducting forest-dwelling woodland caribou research on specific questions related to *Road and Other Corridor Effects*.

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
513	Determine effects of roads at multiple scales on caribou movements, possible range reduction, distribution, and survival (mortality rate).	JJ
465	What is the road density threshold for negative effects on caribou?	MM
434	Determine impact of roads, other linear corridors and associated human traffic on caribou and predator movement.	NN
365	What is the impact of building roads through critical habitat?	LL
357	What are the effects of manmade corridors on caribou use of landscapes?	KK
241	How important are natural and manmade travel corridors?	PP
176	Are major highways barriers to annual or seasonal movement of caribou?	OO

^a Sum of the inverted ranks (1 – 7) for each question.

9. The three (3) most important specific research questions from above that respondents would like to see addressed by the research program at CNFER.

SCORE ^a	SPECIFIC RESEARCH QUESTION	UNIQUE ID
106	Evaluate effects of landscape disturbances created by commercial forestry operations on caribou populations (via individual caribou survival and mortality causes, recruitment, habitat selection at multiple scales, measuring changing abundance of moose, deer and predation by wolves and bears).	C
42	Determine the mechanisms driving forest woodland caribou population dynamics in modified landscapes.	A
37	At what level of disturbance do caribou abandon previously occupied habitat (threshold of disturbance)?	L

^a Sum of the inverted ranks (1 – 3) for each question.

Appendix B. CNFER Forest-Dwelling Woodland Caribou Research Workshop Participants and Assignment to Working Groups.

Working Group	Participant	Affiliation
A	Brad Allison	OMNR-CNFER
	Jim Baker ^a	OMNR-ARDB
	Elston Dzus	Alberta Pacific
	Phil Elkie	OMNR-Forest Policy Section
	Brian McLaren	Lakehead University
	Brent Patterson	OMNR-WRDS
	Kandyd Szuba	Domtar
B	Réhaume Courtois	Québec Natural Resources and Wildlife
	Bill Crins	OMNR-Ontario Parks
	Peter Davis	OMNR-Wildlife Section
	Mick Gauthier	OMNR-Cochrane District
	Gillian McEachern	CPAWS
	Bruce Pond ^a	OMNR-WRDS
	Roger Suffling	University of Waterloo
	Lyle Walton	OMNR-NESI
C	Ted Armstrong	OMNR-Wildlife Section
	Daniel Fortin	Université Laval
	Bruce Ranta	OMNR-Forest Policy Section
	Doug Reid	OMNR-CNFER
	Rob Rempel	OMNR-CNFER
	Art Rodgers ^a	OMNR-CNFER
	Jen Shuter	University of Guelph
D	Ken Abraham	OMNR-WRDS
	Glen Brown	OMNR-NESI
	Vince Crichton	Manitoba Conservation
	Marty Obbard	OMNR-WRDS
	Justina Ray	University of Toronto/WCS
	Jim Schaefer ^a	Trent University
	Darren Sleep	NCASI
	Keith Wade	OMNR-CNFER
Facilitator	Tom Nudds	University of Guelph
Not assigned	Ed Iwachewski	OMNR-CNFER

^a Group leader.

Appendix C. Draft Principles of Decision Analysis and Adaptive Management. Prepared for the Saugeen Ojibway/Canada/Ontario Plenary. Mike Jones (Michigan State University) and Tom Nudds (University of Guelph). 14 February 2003.

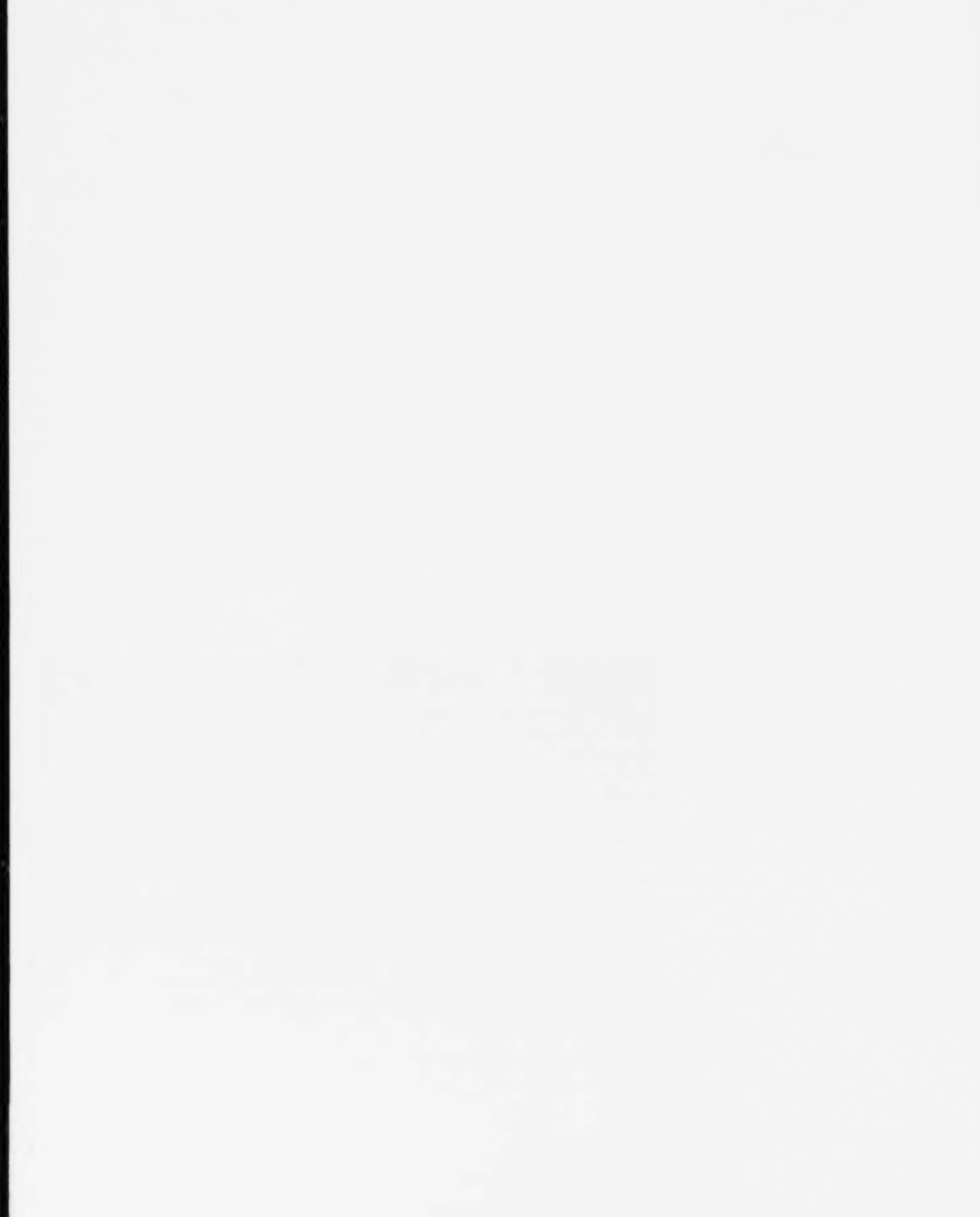
1. Uncertainty is pervasive and has a big effect on ability to make wise decisions.¹
2. DAAM must be clearly understood.²
3. DAAM requires a careful, inclusive specification of the management system.³
4. To be effective, DAAM depends on meaningful involvement of all stakeholders.³
5. Decision analysis and adaptive management depend on one another to be effective.⁴
6. Successful, inclusive DAAM requires these steps:
 - a. All parties involved.
 - b. Inclusive specification of management objectives and options.
 - c. Identification of critical uncertainties, as hypotheses.
 - d. Critical, rigorous examination of evidence for alternative hypotheses.
 - e. Development of models to forecast outcomes of management, given different hypotheses.
 - f. Evaluation and ranking of competing hypotheses by likelihood in light of uncertainty (simple DA).
 - g. Evaluation of experimental management options (DA - value of information analysis).
 - h. Design and implementation of management experiments according to sound principles of experimental design.
 - i. Monitor key responses.
 - j. Update ranking of competing hypotheses by likelihood given monitoring results.

¹ No management decision is without risk. To be sure, learning about risk occurs as part-and-parcel of DA insofar as DA facilitates risk "assessment", but risk is not necessarily reduced as a result. Uncertainty, and hence risk, remain until tests are performed that explicitly address the key uncertainties that present risk, that is, until risk is actually assessed as a result of applying experimental management.

² A clear understanding of DA and AM is essential: combined, they amount to "learning while doing", not "learning, then doing". The latter is referred to now as "muddling through", and is not the preferred option in modern natural resources management. Management agencies often refer to "flexible" management as adaptive management and to "systematic, objective" decision making as decision analysis. This is wrong. Both are incorrect uses of the terms because they fail to explicitly acknowledge uncertainty and the opportunity to learn.

³ Unless the management system is fully specified and inclusive, key uncertainties will remain outside the ability of managers to address through DAAM, thus further contributing to risk. The most advanced, large-scale example of AM currently in place (mallard harvest management) has learned from experience that the proper identification of populations and, by extension, stocks within populations, is a key requisite to successful application of DA and AM. This is generally true of any widespread, renewing, biological populations that represent common property resources. Caribou management boards, for example, successfully brought together all of the users throughout the range of particular migratory herds with a view to addressing key differences of opinion among the users with respect to the factors that affected the shared resource.

⁴ DA and AM are more than simply complementary. Complementarity implies merely existing side-by-side, but not necessarily co-dependent. Experimental management without DA is inefficient, and DA without experimental management is unfinished business.



ISBN 978-1-4249-4665-5
(0.1k P.R. 28 06 07)